European Commission

VMAD SG2 on Virtual/Simulation testing

2nd Meeting

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Joint Research Centre

Agenda

- Common Definitions
- Literature Review
- Next Steps

COMMON DEFINTIONS

- *‘Model-In-the-Loop’* (MIL) is an approach which allows quick algorithmic development without involving dedicated hardware. Usually, this level of development involves high-level abstraction software frameworks running on general-purpose computers.

- *‘Software-In-the-Loop’* (SIL) is where the actual implementation of the developed model will be evaluated on general-purpose hardware. This step requires a complete software implementation very close to the final one. SIL testing is used to describe a test methodology, where executable code such as algorithms (or even an entire controller strategy), is tested within a modelling environment that can help prove or test the software

- *‘Hardware-In-the-Loop’* (HIL) involves the final hardware running the final software with input and output connected to a simulator. HIL testing provides a way of simulating sensors, actuators and mechanical components in a way that connects all the I/O of the Electronic Control Units (ECU) being tested, long before the final system is integrated.

- *‘Vehicle-Hardware-In-the-Loop’* (VHIL) approach. This kind of test is a combination of the HIL and test-drive approaches. Functional as well as integration tests can be done easily and early in the development cycle. As the vehicle is physically locked on the chassis-dynamometer, this system greatly improves the safety of the tests

COMMON DEFINTIONS

- *'Closed Loop Testing'* means a simulation environment does take the actions of the system-in-the loop into account. Simulated objects respond to the actions of the system (e.g. system interacting with a traffic simulatin model)

- *'Open Loop Testing'* means a simulation environment that does not take the actions of the system-in-the loop into account (e.g. system interacting with a recorded traffic situation)

- *'Validation'* is the process of determining the degree to which a model or a simulation is an accurate representation of the real world from the perspective of the intended uses of the simulation.

- *'Verification'* is the process of determining the extent to which an simulation is compliant with its requirements and specifications as detailed in its conceptual models, mathematical models, or other constructs.

- *'Model'* is a description or representation of a system, entity, phenomenon, or process

- *'Simulation*' is an imitation of the behavioral characteristics of a system, entity, phenomenon, or process.

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COMMON DEFINTIONS

- *Stimulation'* is a type of simulation whereby artificially generated signals are provided to real equipment in order to trigger it to produce the result required for verification of the real world, training, maintenance, or for research and development.
- *'Deterministic'* is a term describing a system whose time evolution can be predicted exactly
- *'Probabilistic'* is a term pertaining to non-deterministic events, the outcomes of which are described by a measure of likelihood
- *'Stochastic'* means a processes involving or containing a random variable or variables. Pertaining to chance or probability.
- *'Calibration'* is the process of adjusting numerical or modeling parameters in the model to improve agreement with a referent.
- *'Abstraction'* is the process of selecting the essential aspects of a source system or referent system to be represented in a model or simulation, while ignoring those aspects not relevant to the purpose of the model or simulation. Any modeling abstraction carries with it the assumption that it does not significantly affect the intended uses of the simulation

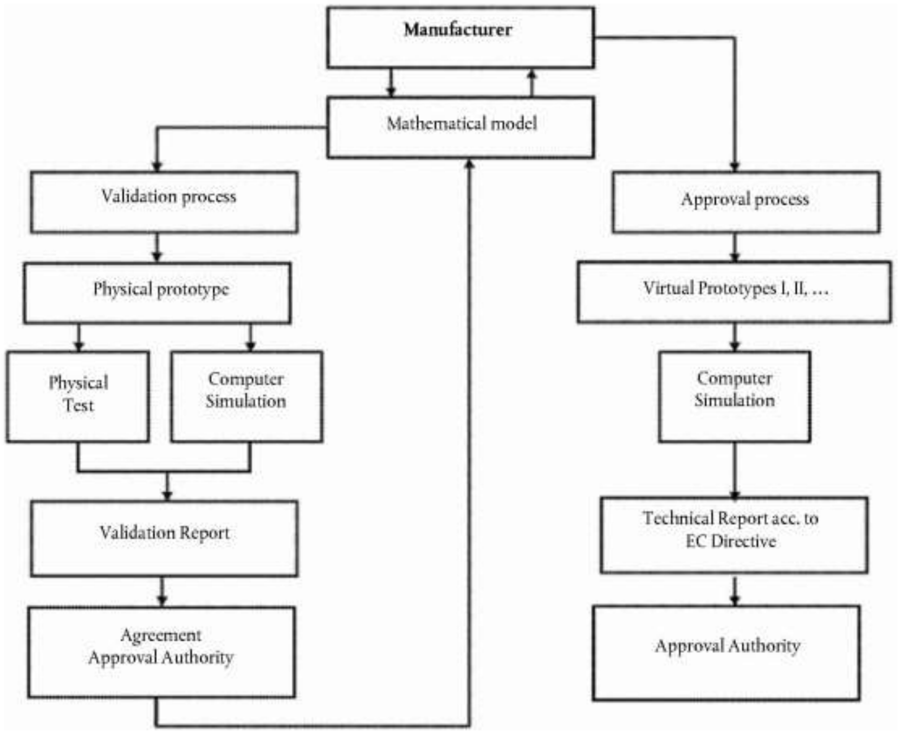
LITERATURE REVIEW

UNECE R140 & (EC) 2018/858

Describes the validation process for a simulation (mathematical model) used in the type approval process. Applicable to a specific set of regulatory acts.

Appendix 3

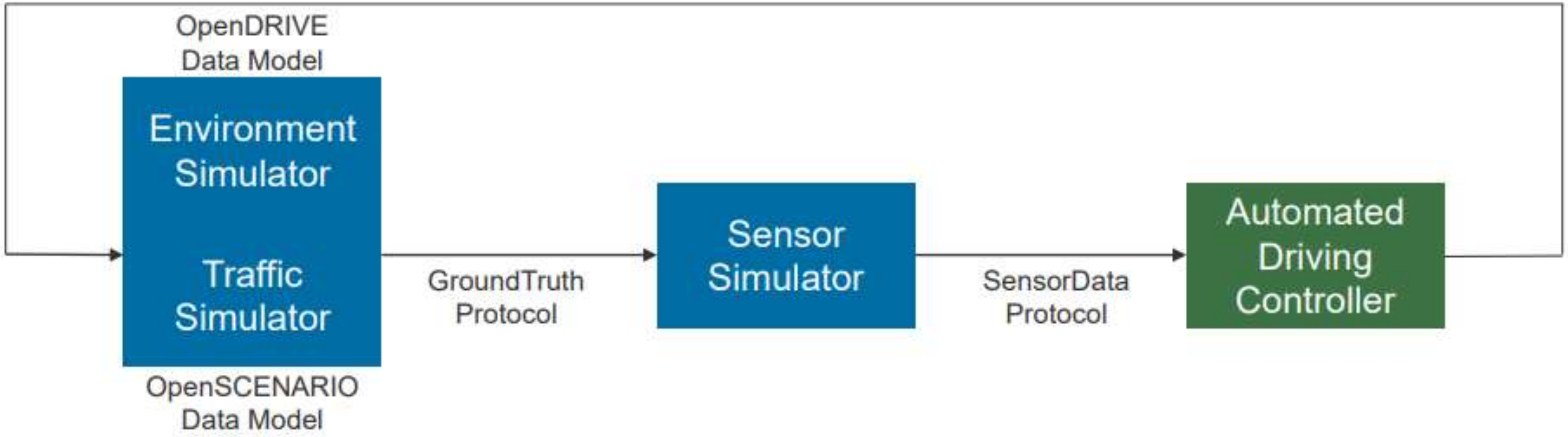
Validation process



LITERATURE REVIEW

ASAM OSI

- OSI: Open Simulation Interface
- A generic interface for the **environment perception of automated driving functions in virtual scenarios**.
- Contains an object-based environment description using message formats for two types of data:
  - GroundTruth: gives an exact view on the simulated objects in a global coordinate system.
  - SensorData: describes the objects in the reference frame of a sensor for environmental perception.

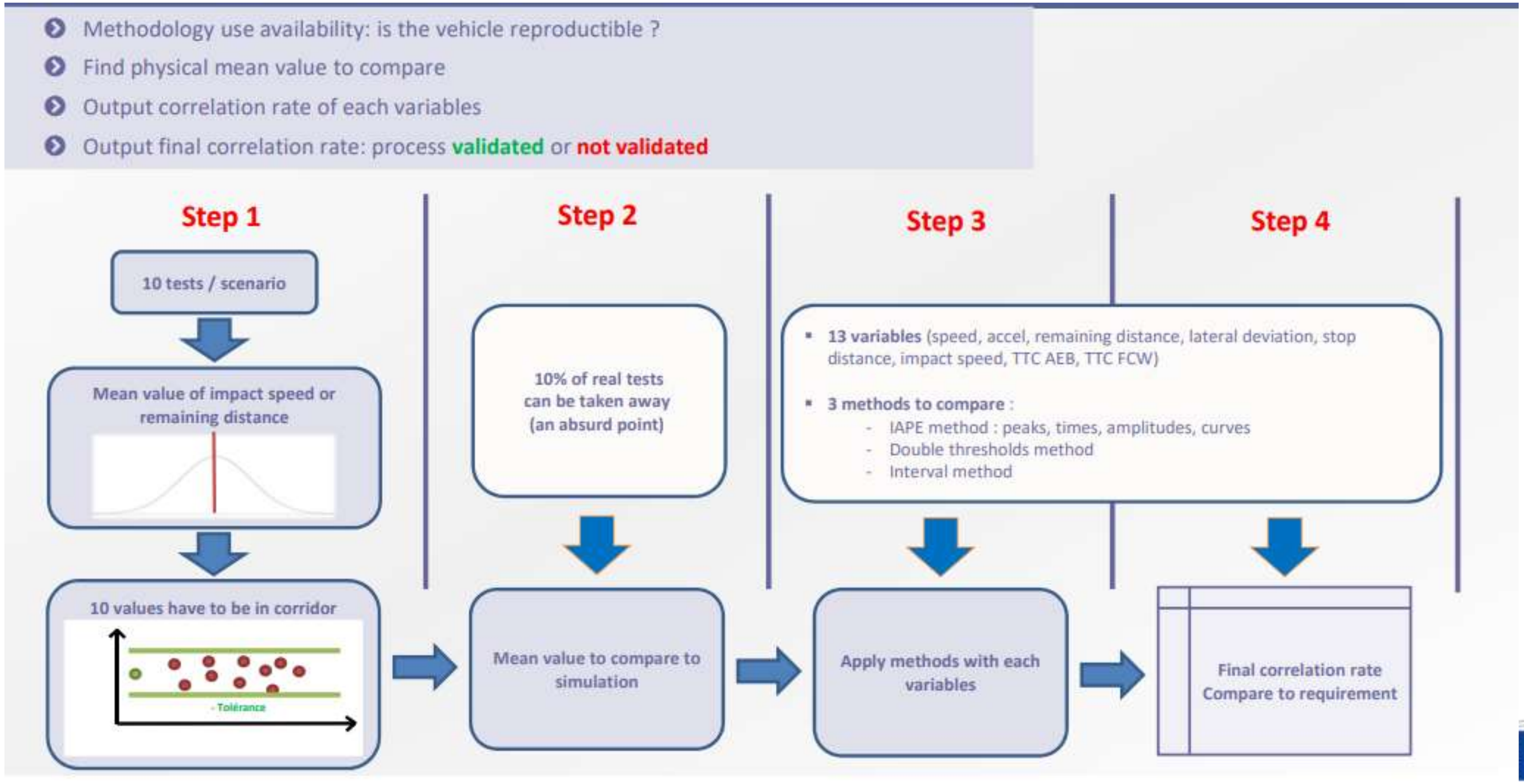


LITERATURE REVIEW

AEBS 12-07 (UTAC) Validation method: Virtual testing

- Describes how different Simulation tools may be used during V&V. e.g. MIL, SIL during verification and HIL, VIL used in validation.
- Proposes a 4 step strategy for validating simulation results + KPIs (IAPE method to quantify correlation rate)

AEBS-12-07



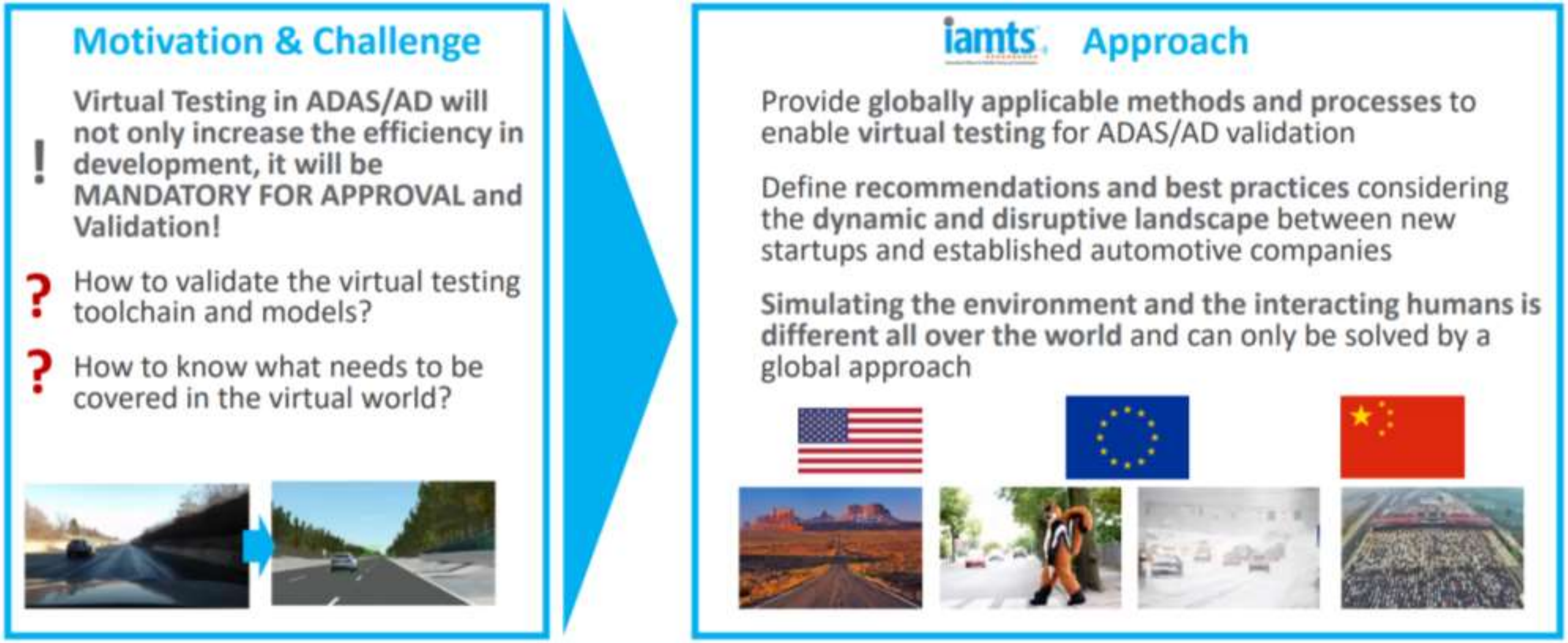
LITERATURE REVIEW

IAMTS WG 3: Correlation Physical and Virtual Testing

- A general process for step by step correlation is defined.
- A publication will be released with a comprehensive analysis of the correlation methods.
- Physical demonstration will be conducted using concrete examples from UNECE R157 (ALKS).

PDF

IAMTS WG3



LITERATURE REVIEW

PDF

NASA TS

NASA's Technical Standard for Models and Simulations (NSAS-STD-7009A)

- The standard provides recommendations on data/documentation that should be provided by the simulation provide

NASA-STD-7009A				
Section	Description	Requirement in this Standard	Applicable (Yes or No)	If No, Enter Rationale
4.2.3b	M&S Verification	[M&S 16] Shall document the domain of verification of all models.		
4.2.5a	M&S Validation	[M&S 17] Shall validate all models.		
4.2.5b	M&S Validation	[M&S 18] Shall document the domain of validation of all models.		
4.2.7a	Uncertainty Characterization in M&S Development	[M&S 19] Shall document any processes and rationale for characterizing uncertainty in the referent data.		
4.2.7b	Uncertainty	[M&S 20] Shall explain and document any mechanisms or constructs related to the incorporation		

- The credibility of M&S-based results is not something that can be assessed directly. However, key factors of credibility may be assessed more directly.
- The quality of each factor is scored through a specific assessment. Results are compared to a minimum threshold

Development			Operations			Supporting Evidence	
Data Pedigree	Verification	Validation	Input Pedigree	Uncertainty Characterization	Results Robustness	M&S History	M&S Process/Product Mgt

LITERATURE REVIEW

NASA's Technical Standard for Models and Simulations (NSAS-STD-7009A)

M&S Results Influence					
5: Controlling	(G)	(Y)	(R)	(R)	(R)
4: Significant	(G)	(Y)	(Y)	(R)	(R)
3: Moderate	(G)	(Y)	(Y)	(Y)	(R)
2: Minor	(G)	(G)	(G)	(Y)	(Y)
1: Negligible	(G)	(G)	(G)	(G)	(Y)
	I: Negligible	II: Minor	III: Moderate	IV: Significant	V: Catastrophic
	Decision Consequence				

A 'criticality assessment' is used to determine how rigorously a simulation tool should follow NASA's technical requirements based on: consequences to human safety / mission success, and the degree in which simulated results influence a decision.

- Those simulation that are assessed to fall within the red (R) are clear candidates for fully following this NASA Technical Standard.
- The simulation that are assessed to fall within the yellow (Y) boxes may or may not be candidates for fully following this NASA Technical Standard at the discretion of program/project management in collaboration with the Technical Authority.
- There is not a critical driving force for those falling within the green (G) boxes.

LITERATURE REVIEW

SAFAD

ISO TR 4804 – Safety First for Automated Driving

- Highlights different types of simulation
- Provides a good indication on which simulation types may be useful for all aspects of the HW / SW testing
- Proposes to test the validity of the full system simulation for a subset of corner cases against real-world experience.
- States that the final confidence statement about the automated driving system safety should account for the remaining uncertainty about the validity of the simulation
- It mentions that simulation may be used to estimate the system’s behavior after a human takeover

Test Platform and Test Item

Test Item ▶ / ▼ Test Platform	Target SW (Code)	Target HW (ECU)	Vehicle	Driver	Driving Environment
SiL (Simulation in the Closed Loop)	Virtual / Real	Virtual	Virtual	Virtual / None	Virtual
SW Repro (Software Repro-cessing)	Virtual / Real	Virtual	None	None	Virtual
HiL (Hardware in the Closed Loop)	Real	Real	Virtual	Virtual / None	Virtual
HW Repro (Hardware Repro-cessing)	Real	Real	None	None	Virtual
DiL (Driver in the Loop)	Real	Virtual / None	Virtual / None	Real	Virtual / Real
PG (Proving Ground)	Real	Real	Real	Real / Robot	Real
OR (Open Road)	Real	Real	Real	Real	Real

Keep in touch

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Thank you

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